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MATLAB based modeling to study the performance of different MPPT techniques used for solar PV system under various operating conditions

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ABSTRACT

Although solar photovoltaic technology is one of the matured technologies, its initial high cost and low efficiency have not made it fully attractive as an alternative option for electricity users. Hence it is very critical to utilize the maximum available solar power of the array and to operate the PV array at its highest energy conversion output. For this, the solar PV generating system has to operate at the maximum power output point. Since the maximum power point varies with radiation and temperature, it is difficult to maintain optimum power operation at all radiation levels. Over the years, many MPPT techniques have been advocated, developed and implemented. These methods vary in several aspects such as complexity, required number of sensors, convergence speed, cost, range of effectiveness, ease of hardware implementation etc. Although different methods have been developed by different research groups, very little literature is available, where different MPPT techniques/methods are compared in terms of energy capture, conversion efficiency, response time and reliability. This paper compares the performance of different MPPT methods that are currently used in a solar PV system and also advocates a new MPPT technique which offers better performance than the existing ones. The methodology adopted for analysis is as follows: Initially, a MATLAB based solar PV array model is first developed and validated; then, different MPPT techniques are employed on this PV array under varying temperature and insolation conditions to study the effectiveness of the particular MPPT technique under consideration.

Contents

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1. Introduction

Solar photovoltaic (SPV) systems are considered as one of the most reliable and matured technologies amongst various renewable energy sources. However, high installation cost and low commercial efficiency (12–15%) of the SPV system make it an unattractive choice for those electricity users who look for an alternative despite the government subsidies. Although SPV system prices have decreased considerably during the last years due to new developments in the thin-film technology and manufacturing process [1], electricity from PV arrays is still expensive as compared to the existing fossil fuel generated electricity from the utility grid. Hence, it is important that the SPV array is used to its maximum potential. In order to achieve that, the SPV system has to be operated at its maximum power point, which will be tracked by different Maximum power point tracking (MPPT) techniques.

Standalone PV generation systems are attractive for remote areas. However, the efficiency of the PV system depends on several climatic factors like the solar radiation, ambient temperature and the state of the solar panels such as their age, cleanliness etc. Since the maximum power point varies with radiation and temperature, it is difficult to maintain optimum matching at all radiation levels. Therefore, many research papers have focused on increasing the efficiency of the overall solar PV system by ensuring maximum power capture by adjusting the operating point of the DC–DC converter. A DC–DC converter acts as the interface between the load and the SPV module. By changing the duty cycle, the load impedance as seen by the source is varied and matched such that maximum power is harnessed from the PV source by appropriately maintaining the voltage–current relationship. Over the years, many MPPT techniques have been advocated, developed and implemented. These methods vary in several aspects such as complexity, required number of sensors, convergence speed, cost, range of effectiveness, ease of hardware implementation etc [2]. There are around 20 MPPT techniques that have been developed in the last two decades. Some of these methods/techniques are [3]:

- Hill climbing,
- Perturb and observe (P&O),
- Incremental conductance (IncCond),
- Fractional open circuit voltage (V_{oc}),
- Fractional short circuit current (I_{sc}),
- Ripple correlation control (RCC),
- Current sweep,
- Fuzzy logic and neural network control,
- Load current or load voltage maximization,
- DC link capacitor droop control etc.

Over the years, several researchers have studied the characteristics of PV modules and various MPPT techniques have been developed [4–15]. Xiao and Dunford [5] have worked on P&O method to reduce the system oscillation near the maximum power point (MPP) for both hill climbing and P&O methods. They have developed variable perturbation size that gets smaller as the operating point approaches maximum power point (MPP). Hsiao and Chen [6] have presented a three-point weight comparison P&O method to address the issue of failure of P&O method under rapidly changing atmospheric conditions. Hussain [7] developed a new MPPT algorithm based on the fact that the maximum peak operating point (MPOP) of a PV generator can be tracked accurately by comparing the incremental and instantaneous conductance of the PV array. The work was carried out both in simulation and experimental prototype, with results showing that the developed incremental conductance (IntCond) algorithm successfully tracks the MPP, even in rapidly changing atmospheric conditions; it also results in higher efficiency than the other MPPT algorithms in terms of total PV energy transferred to the load. Patcharaprakiti et al. [8] presented an adaptive fuzzy logic controller that constantly tunes the membership functions and the rule based tables so that the optimum performance in tracking the true MPP is achieved.

Several research papers propose different techniques for achieving MPPT, however, a comprehensive comparison of these techniques, in terms of their cost effectiveness, conversion efficiency, range of temperatures and insolation levels under which they can operate and reliability is not available in the literature. In some papers [4–6], a comparison of two MPPT methods is carried out but the comparison is made at the solar module level rather than for the entire solar PV system. Since I–V and P–V characteristic of the single module do not depict multiple peaks which are commonly shown in the I–V and P–V characteristics of the solar PV array under non-uniform insolation, solar PV array is a far more practical representation of the actual solar PV system, attention should be given to study and compare different MPPT methods used with a solar PV array. This paper envisages comparing the performances of some of the existing MPPT techniques in a solar PV system in terms of energy captured, conversion efficiency, reliability etc. Further, it also advocates a new MPPT methodology which yields a better performance than the existing techniques.

The paper is structured as follows. The overall configuration of the SPV system is described in Section 2. The description of different MPPT techniques and algorithms under study is presented in Section 3. Modeling and simulation of entire SPV system is presented in Section 4. Performance assessment of different MPPT techniques under similar operating conditions is presented in Section 5. A novel MPPT technique is advocated in Section 6 along with its performance characteristics. Finally conclusion is presented in Section 7

2. Overall system configuration

When a PV array is directly connected to a load or for charging a battery, the operating point of the system is at the intersection of

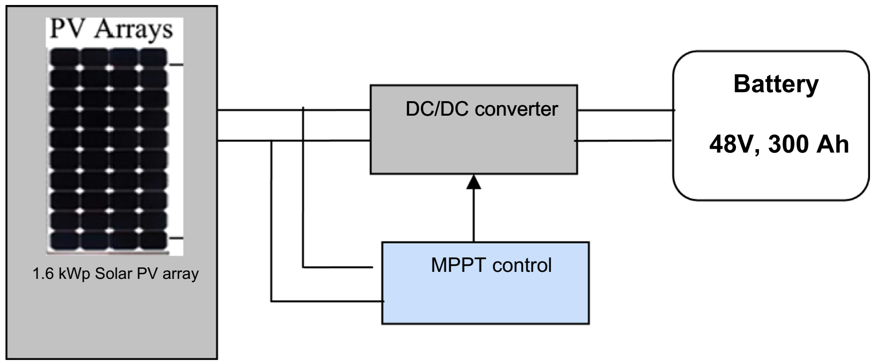

Fig. 1. Block diagram of the proposed PV system with MPP Tracker.

Table 1
Different MPPT techniques.

MPPT technique	PV array dependent	True MPPT	Analog or digital	Periodic tuning	Convergence speed	Implementation complexity	Sensed parameter
Constant voltage	Yes	No	Both	Yes	Medium	Low	Voltage
Incremental conductance	No	Yes	Digital	No	Varies	Medium	Voltage, Current
Perturb and observe	No	Yes	Both	No	Varies	Low	Voltage
Fractional I_{sc}	Yes	No	Both	Yes	Medium	Medium	Current

the *I–V* curve of the SPV array and the load line. In general, this operating point is not at the MPP of the SPV array. Thus in a SPV battery charging system, the PV array is oversized to charge the battery in a typical day with average insolation. This leads to a huge capital investment. In order to overcome this disadvantage, a switching mode power converter called Maximum Power Point Tracker is used to maintain the operating point of the SPV array at MPP. The block diagram of the proposed solar PV system for charging a lead acid battery with MPP Tracker is shown in Fig. 1.

The proposed system consists of a 1.6 kWp solar PV array which is connected to a buck converter to charge a 48 V, 300 Ah battery. According to the MPPT technique used, a V_{ref} corresponding to V_{MPP} is created which regulates the duty cycle of the converter and forces the solar array to work at the MPP. If a proper MPPT algorithm is chosen and implemented, then the MPPT can locate and track the MPP of the PV array continuously. Although the current requirement for charging the battery depends upon the charging profile and varies with state of charge of the battery, for a battery charging option, it might not be possible to run the module always at the MPPT mode. However, since the purpose of this paper is to assess the performance of different MPPT techniques under similar operating conditions, a larger size battery whose current requirement (at C/10 rate) is much larger as compared to the current provided by solar module at maximum power is considered. There are several MPPT techniques/algorithms that exist and Table 1 shows different MPPT techniques that were considered in this research work with their varied features [4].

The purpose of this work is to compare the performances of various MPPT techniques in a solar PV system working under similar operating conditions, i.e. *solar insolation and temperature*. The following sections describe the control design for different MPPT algorithms.

3. MPPT control algorithms

MPPT algorithms work in such a way as to modify the duty ratio of the DC–DC converter at the output of the solar array such that the load impedance visualized by the solar PV array will make it operate at the MPP for a given temperature and insolation. The following sections describe some of the MPPT algorithms.

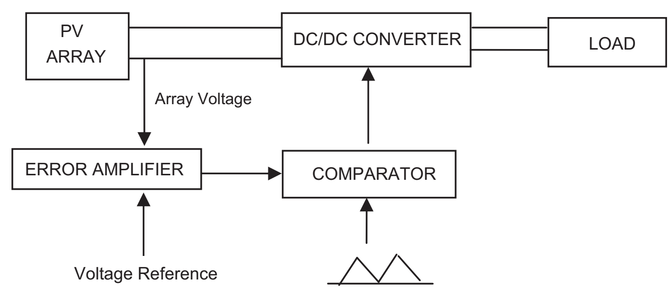

Fig. 2. Control topology for the constant voltage based MPPT.

3.1. MPPT control with constant voltage

The basis for the constant voltage (CV) algorithm lies in the fact that the ratio of the voltage of the array at MPP V_{mpp} to its open-circuit voltage V_{oc} is approximately a constant and generally around 0.76 time of the V_{oc} of the solar module in any given solar insolation [9]. In other word, V_{mpp}/V_{oc}–$K<1$(in this research work, it is considered as 0.76).

The block diagram representation for the MPPT control with constant voltage is given in Fig. 2

The constant voltage algorithm can be implemented using the flowchart given below in Fig. 3

Constant voltage control can be easily implemented with analog hardware. Here, the reference voltage is obtained by multiplying 0.76 with the V_{oc} of the solar module for any given solar insolation.

3.2. MPPT control with perturb and observe method

Perturb and observe (P&O) method is also known as hill climbing method. The P&O algorithms operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage or current and comparing the PV output power with that

of the previous output power. In P&O method, a small voltage perturbation in a certain working voltage of PV array is made simultaneously observing the change in direction of output power. If the output power increases, then the perturbation of the voltage is made in the same direction otherwise perturbation against the original direction should be made. Due to the fixed perturbation step, oscillations occur near the MPP, which reduces the power generation efficiency and affects stability of the entire system adversely. Also, if the step change in the perturbation is large, then the response time to achieve the maximum power is fast, however oscillations near MPP will also be large. On the other hand, if the step change is small, oscillations will be minute at the MPP but the tracking time will be very long. Therefore, selecting the appropriate step size is the key for P&O method to achieve the desired effect. P&O involves perturbation in the PV array voltage to achieve the MPP. When connected to a DC–DC converter, perturbing the duty ratio of power converter perturbs the PV array current and consequently perturbs the PV array voltage. It is known that incrementing the voltage increases the power when operating on the left of the MPP and decreases the power when on the right of the MPP. Therefore,

$$\text{If } \frac{dP}{dV} > 0; \quad V_{ref} = V_{ref} + dV \tag{1}$$

$$\text{If} \frac{dP}{dV} < 0; \quad V_{ref} = V_{ref} - dV \tag{2}$$

and accordingly the perturbation is given.

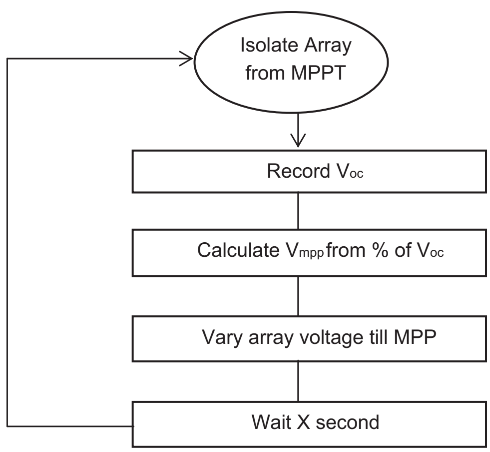

Fig. 3. Flow diagram of constant voltage algorithm.

3.3. MPPT control with variable step perturb and observe method

In P&O, if the PV array operating voltage changes and power increases ($dP/dVPV > 0$), the control system moves the PV array operating point in the same direction further; otherwise the operating point is moved in the opposite direction. A common problem in P&O algorithms is that the array terminal voltage is perturbed every MPPT cycle; therefore when the MPP is reached, the output power oscillates around the maximum, resulting in power loss in the PV system. This is especially true in constant or slowly-varying atmospheric conditions. Furthermore, P&O methods can fail under rapidly changing atmospheric conditions. In order to circumvent this problem, P&O method with variable step size is advocated in several papers; in this modified P&O method, a large perturbation step is adopted when the present operating point is far from the MPP whereas a small step size is adopted in the close vicinity of MPP. Fig. 4 shows the flow chart for P&O based MPPT technique.

3.4. MPPT control with incremental conductance

The P&O method occasionally fails to track the fast changing MPP point in the correct direction during fast changing atmospheric condition. For this reason, incremental conductance method is used. Fig. 5 shows the control topology for incremental conductance based MPPT.

The incremental conductance algorithm is derived by differentiating the PV array power with respect to voltage and setting the result equal to zero. This is shown in Eq. (3)

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = 1 + V\frac{dI}{dV} = 0 \text{ at the MPP} \tag{3}$$

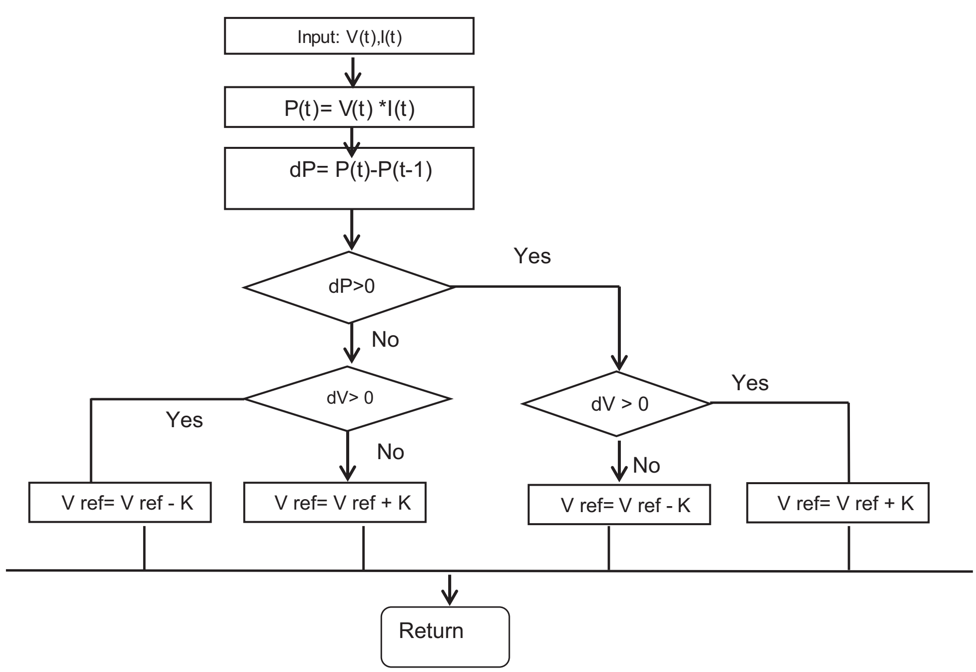

Fig. 4. Flow chart for perturb and observe based MPPT.

Rearranging Eq. (3) gives

$$-\frac{I}{V}=\frac{dI}{dV} \text{ at MPP} \tag{4}$$

$$\frac{dI}{dV}>-\frac{I}{V}; \quad \left(\frac{dP}{dV}>0\right) \tag{5}$$

and

$$\frac{dI}{dV}<-\frac{I}{V}; \quad \left(\frac{dP}{dV}<0\right)$$

Therefore,

$$\text{If } \left(\frac{dI}{dV}>-\frac{I}{V}\right); \quad V_{ref}=V_{ref}+dV \tag{6}$$

$$\text{If } \left(\frac{dI}{dV}<-\frac{I}{V}\right); \quad V_{ref}=V_{ref}-dV \tag{7}$$

The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (dI/dV) as shown in the flow diagram below in Fig. 6

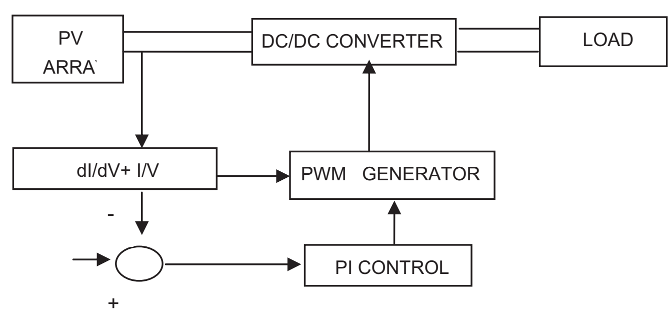

Fig. 5. Control topology for incremental conductance based MPPT.

3.5. *MPPT control with fractional short circuit current*

In fractional short circuit current, $I_{MPP}=k\,I_{sc}$. This 'k' has to be determined from the solar array in use; generally 'k' lies between 0.78 and 0.82. But measuring I_{sc} during operation is difficult. An additional switch usually has to be added to the power converter to periodically short the PV array so that I_{sc} can be measured using a current sensor. This increases the number of components and cost. Further, MPP is never perfectly matched when this algorithm is adopted. Fig. 7 shows the topology of the fractional current

4. Modeling and simulation

4.1. *Modeling and simulation of solar PV array*

A mathematical model is developed for the 1.6 kWp SPV array. Fig. 8 depicts the equivalent circuit of a single solar cell using 2 diodes. The equation that represents I–V characteristics of solar cell is derived from a more accurate two exponential diode model, where

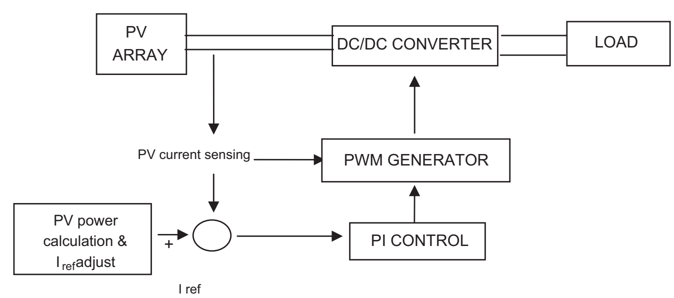

Fig. 7. Topology for factional current.

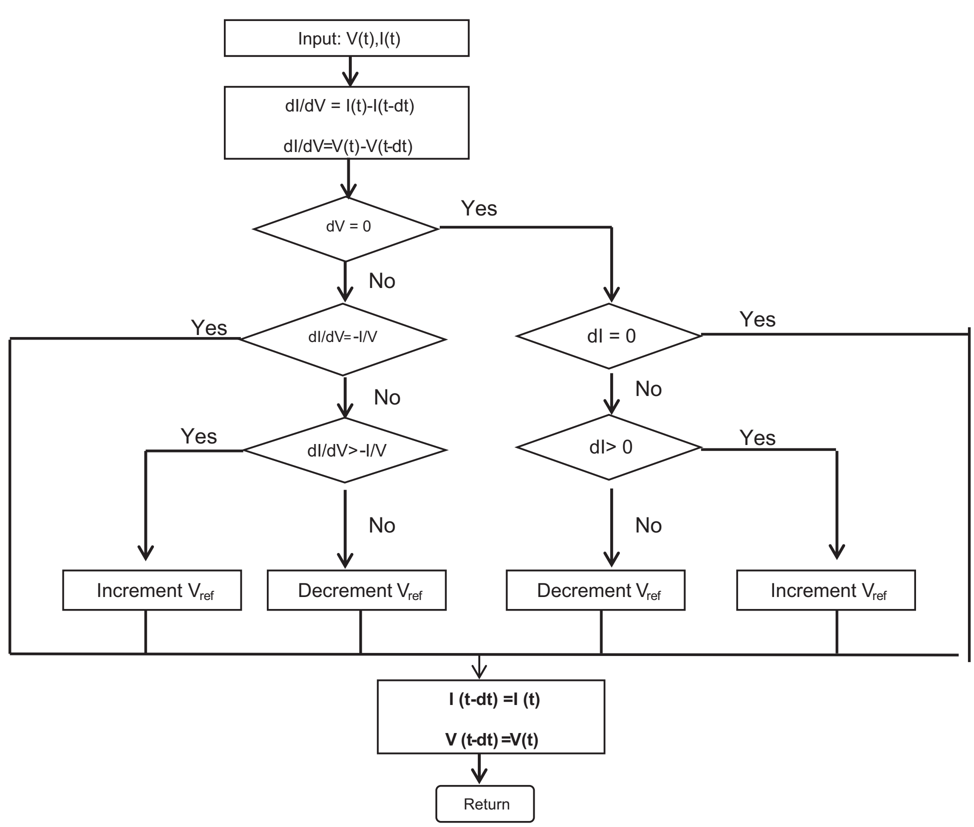

Fig. 6. Flow diagram of incremental conductance.

the output current of the solar cell can be derived as

$$I = I_L - I_0[\exp^{q(V+IRs)/n_1 kT} - 1] - I_{01}[\exp^{q(V+IRs)/n_2 kT} - 1) - (V+IR_s)/R_p \quad (8)$$

where I_L is light-induced current of the solar cell; I_0 is saturation current of the first diode; I_{01} is saturation current of the second diode; k is Boltzmann constant; T is device operating temperature parameter value; q is elementary charge on an electron; n_1 is ideality factor (diode emission coefficient) of the first diode; n_1 is ideality factor (diode emission coefficient) of the first diode; n_2 is ideality factor (diode emission coefficient) of the second diode; V is voltage across the solar cell electrical ports.

A 1.6 kWp solar PV array model is developed in simulink by using the mathematical model where eight number of solar PV module, each with rated power of 50 Wp, is connected in series to form the solar PV sub array and there are 4 such sub arrays that are connected in parallel to make the 1.6 kWp solar PV array. The PV array has maximum power of 1.602 W at V_{MPP} of 89.9 V. The basic model of SPV array is shown in Fig. 9.

4.2. Modeling and simulation of 1.6 kWp solar PV array with MPPT for battery charging

1.6 kWp SPV array is connected with the 48 V, 300 A h battery bank through buck converter. The existing battery model in the simulink is used to create the 48 V, 300 Ah battery bank where 4 numbers of 12 V, 150 Ah batteries are connected in series and there are two such strings connected in parallel to make a 48 V, 300 Ah battery bank. Various MPPT algorithms such as constant voltage, Incremental conductance, perturb and observe and variable step size perturb and observe have been implemented by writing the corresponding algorithms in the form of m-files in MATLAB environment. The basic simulated model of 1.6 kWp solar PV with MPPT for battery charging is shown in Fig. 10

Based on the type of MPPT techniques used, the specific m-file corresponding to the specific MPPT technique is called to simulate the MPPT blocks. The MPPT algorithm generates a reference voltage (V_{ref}) which corresponds to voltage at MPP. A PI controller is used to process the difference between the output voltage of the solar PV array and V_{ref} to yield the duty ratio that would make the error zero. The output of the buck converters is regulated by modulating the duty ratio in order to get a regulated voltage of 60 V which is sufficient to charge a 48 V battery.

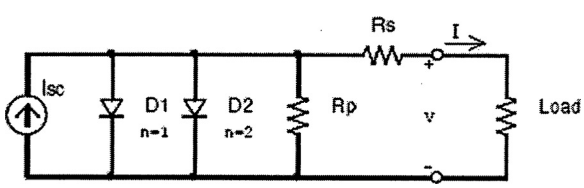

Fig. 8. Circuit diagram for solar cell.

5. Results and discussions

5.1. Variation of power profile of 1.6 kWp SPV system with different MPPT techniques at fixed solar insolation (G) = 1000 W/m^2 and ambient temperature (T) = 300 K

5.1.1. PV system with constant voltage MPPT techniques

1.6 kWp SPV system is simulated for fixed value of G and T using Constant voltage MPPT algorithm. The value of G is 1000 W/m^2 and T is 300 K. Constant voltage MPPT algorithms fix the reference voltage at approximately 0.76 of open circuit voltage (V_{oc}). This might be away from the exact MPP point but is very stable when the variation in insolation is small. Fig. 11 shows the power, voltage and current characteristics. It is observed that voltage ripple is very small and energy delivered in to load is appreciable in this case.

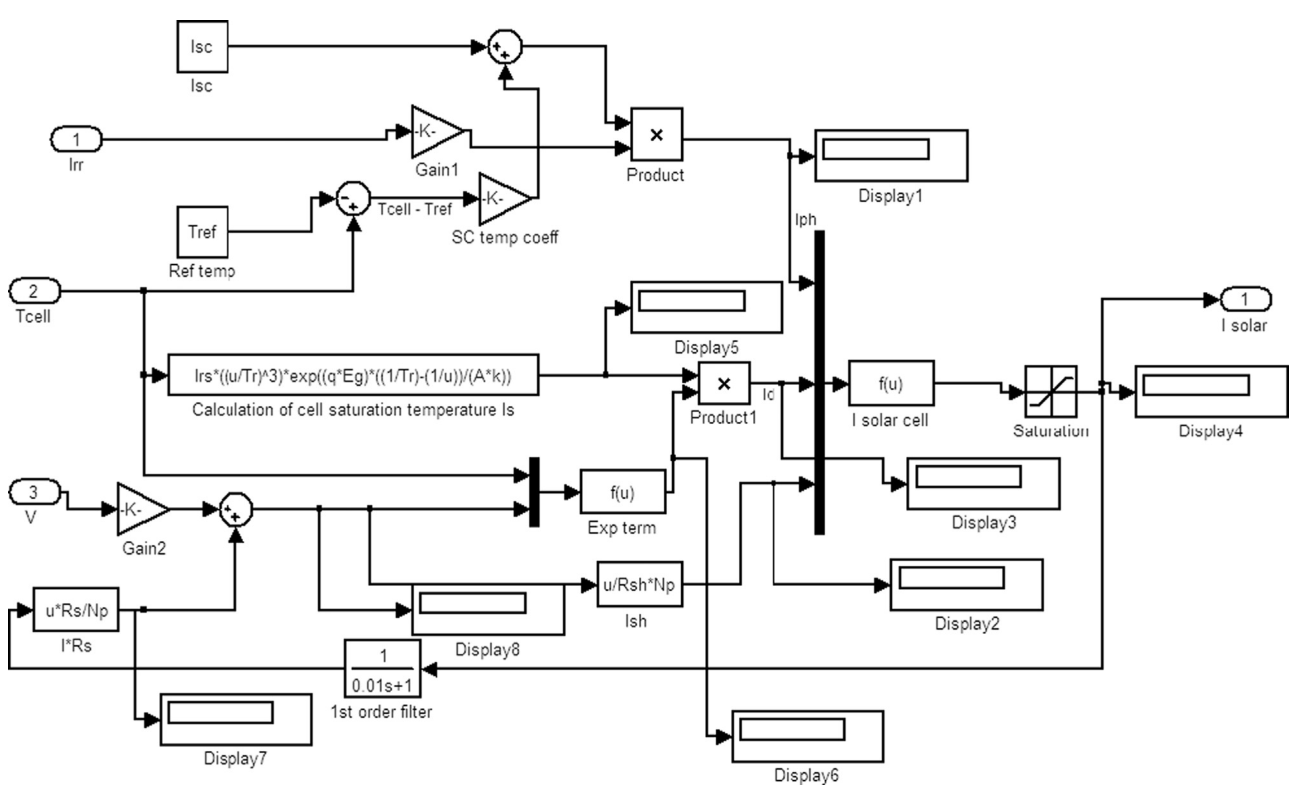

Fig. 9. Basic model of SPV array.

5.1.2. PV system with incremental conductance MPPT technique

1.6 kWp system is simulated for fixed value of G and T using incremental conductance MPPT algorithm. The value of G is 1000 W/m^2 and T is 300 K. Incremental conductance is very accurate with very little voltage ripple at stable point and large energy delivered. As seen from Fig. 12 power ripple is just 0.8 W.

5.1.3. PV system with perturb and observe MPPT technique

1.6 kWp system is simulated for fixed value of G and T using perturb and observe (P&O) MPPT algorithm. The value of G is 1000 W/m^2 and T is 300 K. This algorithm continuously perturbs the voltage by 0.01 V in every 5 μs. and accordingly allows the reference voltage to change at every step in order to track the MPP. Since the step function is quite fast, a large oscillations in voltage, current and power are observed, and hence more power loss occurs in perturb and observe MPPT technique. As seen from Fig. 13, power ripple is 60 W and energy delivered is much less than constant voltage or incremental conductance. However through simulation, it is found that the oscillation around MPP can be reduced from 60 W to 10 W if the voltage is perturbed to 0.0001 V in every 5 μs.

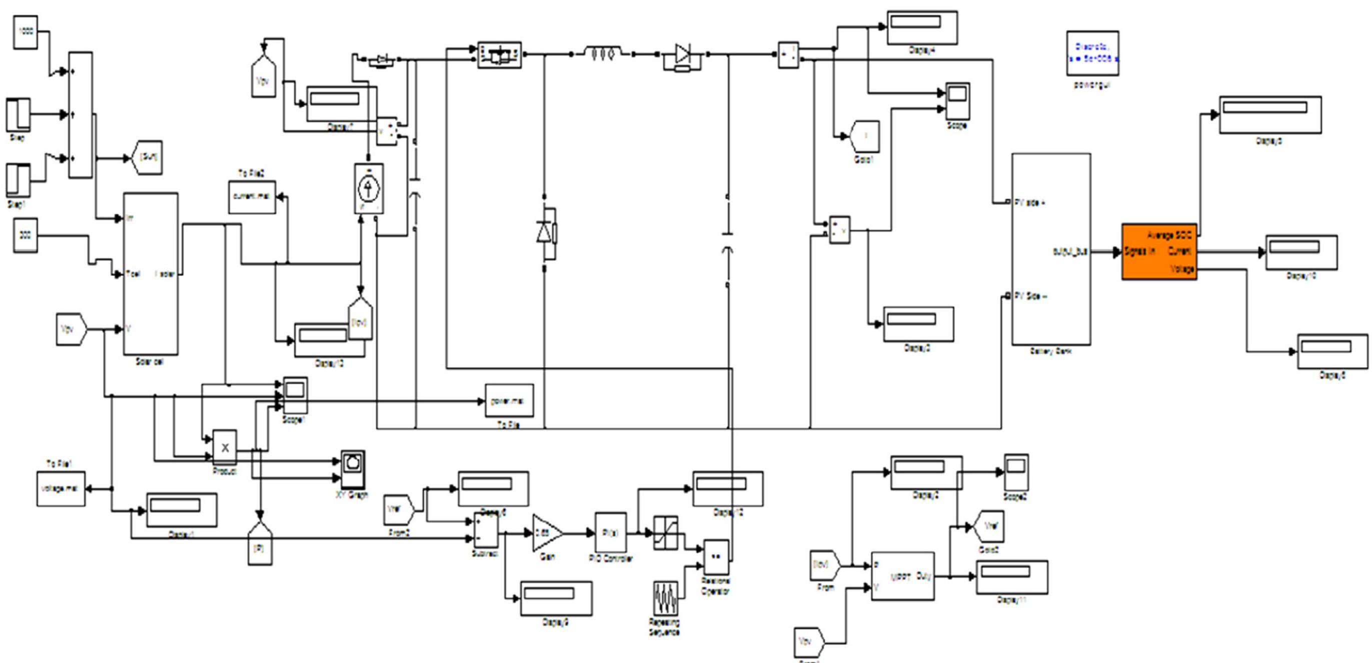

Fig. 10. Simulated model of 1.6 kWp solar PV with MPPT for battery charging.

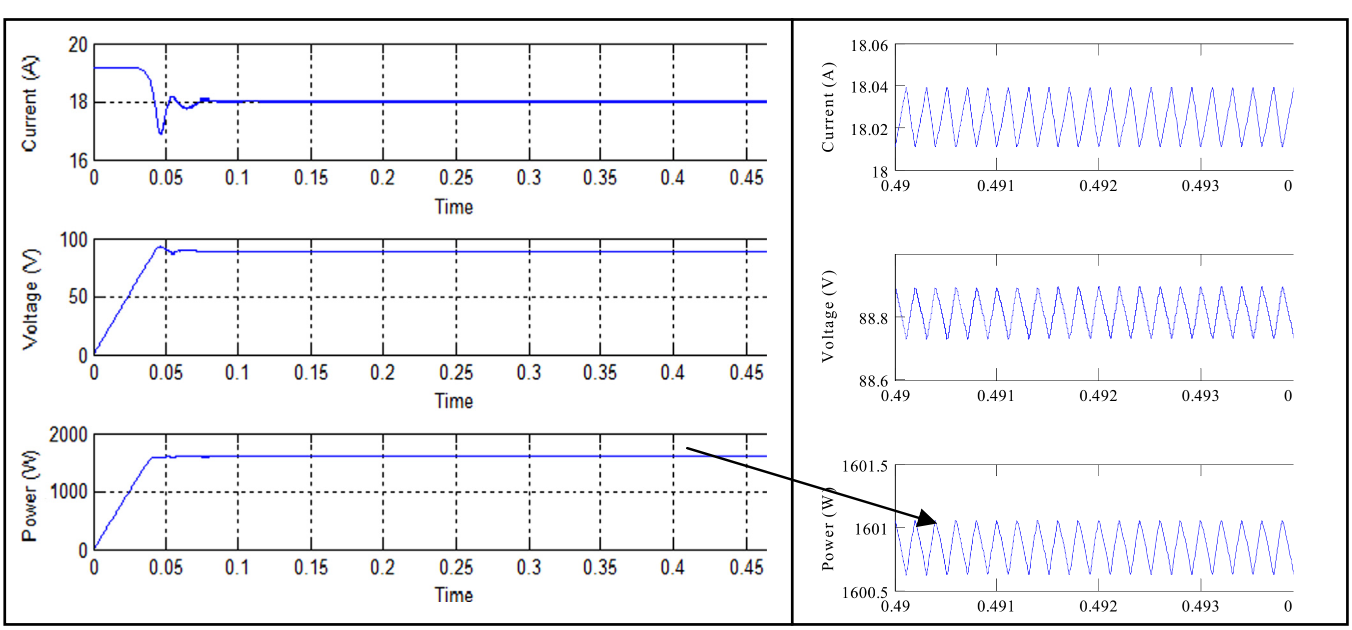

Fig. 11. Power, voltage and current for constant voltage MPPT with fixed G=1000 W/m^2 and T=300 K.

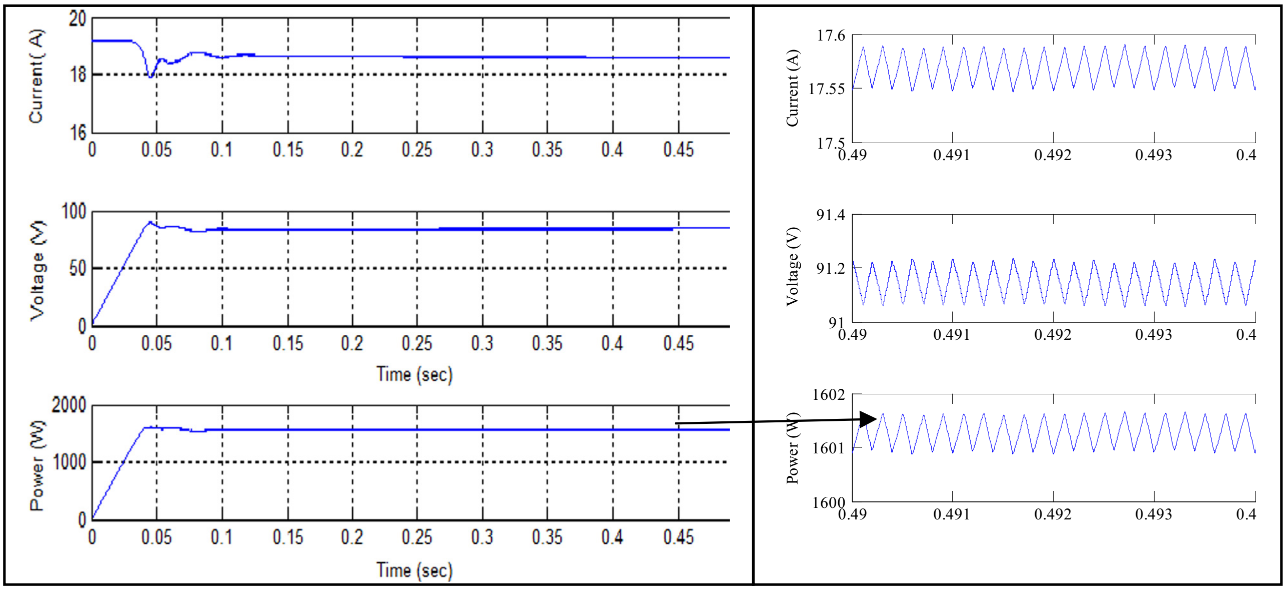

Fig. 12. Power, voltage and current for incremental conductance with fixed $G = 1000$ W/m^2 and $T = 300$ K.

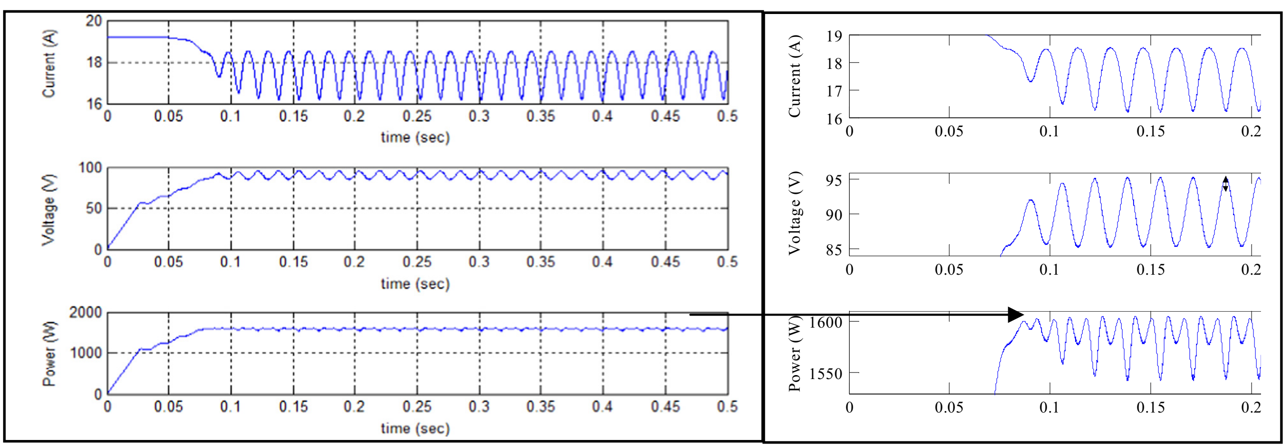

Fig. 13. Power, voltage and current for perturb and observe with fixed $G = 1000$ W/m^2 and $T = 300$ K.

5.1.4. PV system with variable step size perturb and observe MPPT technique

Here initially the voltage step change is 0.01 V for every 5 μs and then the perturbation size is reduced to 0.0001 V near the maximum power point i.e. till the power reaches ± 10% of the Maximum power point (in this case ± 20 W of 1600 Wp). It can be observed that oscillations in power are negligible (as shown in Fig. 14); however, the response time to achieve the MPP is quite large as compared to that of the normal P&O method.

5.2. Comparative assessment of different MPPT techniques under uniform G

The *P–V* curve for the solar PV array is plotted for all the four MPPT techniques under uniform solar insolation of 1000 W/m^2 and temperature of 300 K. Fig. 15 shows the *P–V* plots of all the four MPPT techniques.

Table 2 shows that comparative performance assessment of different MPPT techniques when connected to the same 1.6 kW solar PV array and operated under uniform *G* of 1000 W/m^2 and temperature of 300 K. The performance is assessed in terms of energy generated by PV array in half an hour; the oscillation in power at MPP, the response times to achieve the MPP. It can be observed that in uniform insolation, the energy generated by P&O is the least as compared to other three MPPT techniques. It is primarily due to the large oscillation of power at around MPP (refer to Fig. 13).

At the same time it is also noticed that although the energy generated by using variable step size P&O and Inc Conductance are higher than the other two methods; the response time in these case are very large, particularly in case of variable step size P&O. Thus a trade-off between energy generated and response time needs to be arrived at to get the most effective MPPT algorithm.

5.3. Variation of power profile of 1.6 kWp SPV system with different MPPT techniques at varying G and constant T = 300 K

5.3.1. PV system with constant voltage

For constant voltage *G* is stepped down to 200 W/m^2 from 1000 W/m^2 at 0.1 s, depicting cloudy weather and again it comes to 900 W/m^2 at 0.12 s depicting clearing of the cloudy region. Fig. 16 shows the current, voltage and power profile of PV system with constant voltage MPPT algorithm and when operated under varying *G* and constant *T*.

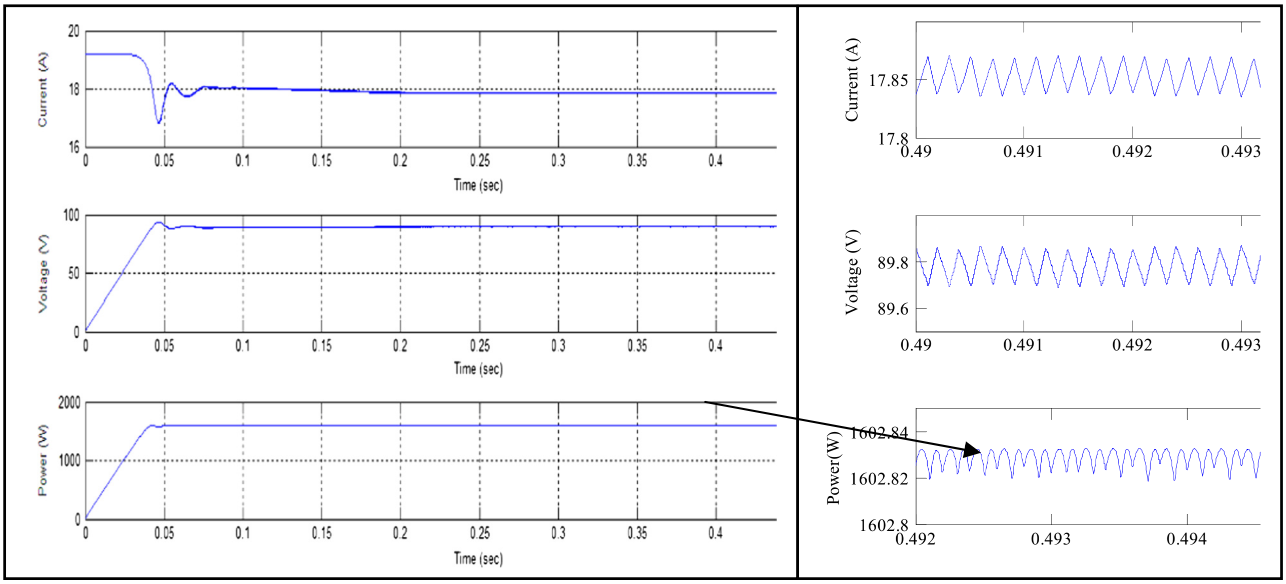

Fig. 14. Power, voltage and current for variable step size perturb and observe with fixed $G = 1000$ W/m^2 and $T = 300$ K.

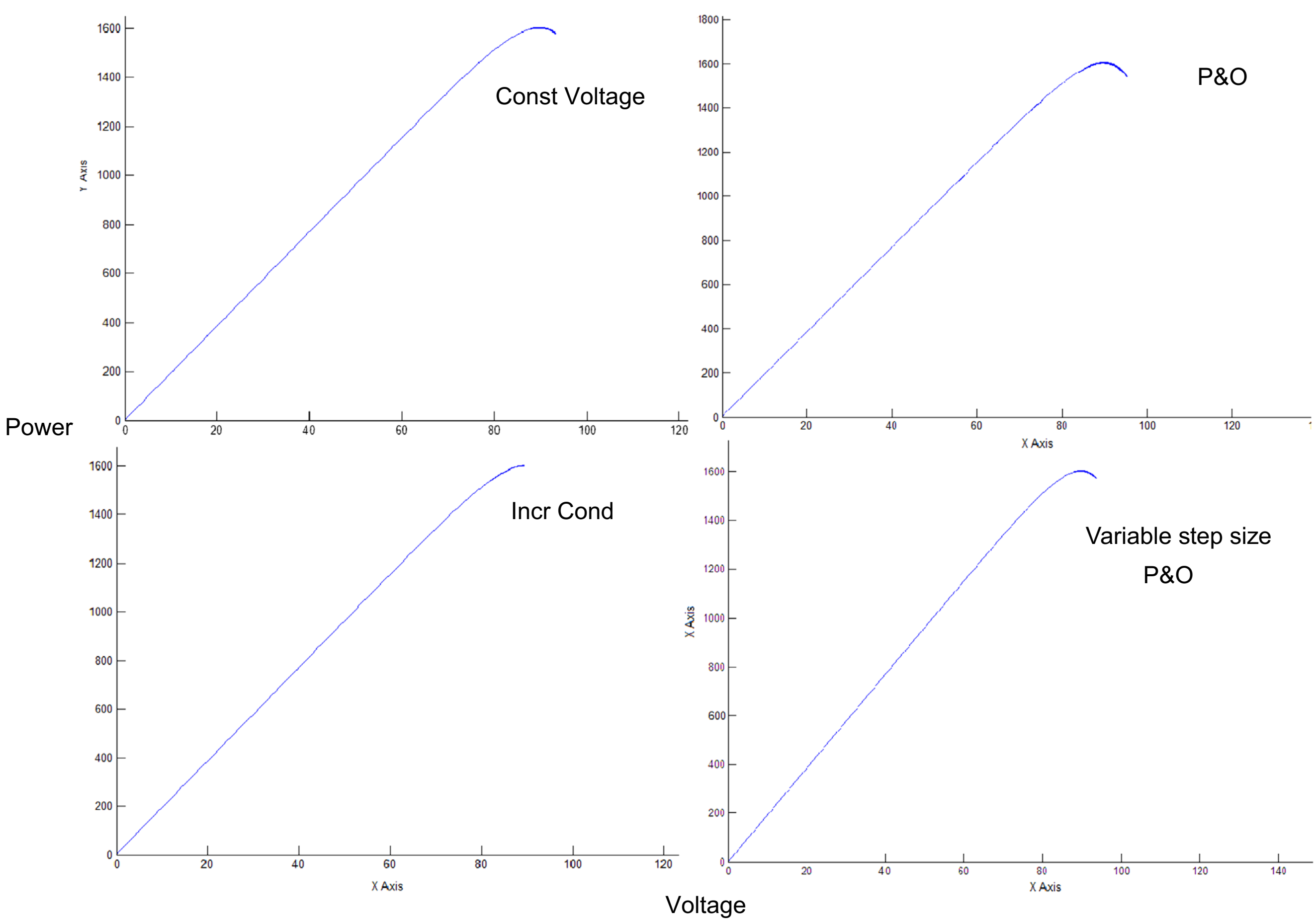

Fig. 15. *P–V* plots of 1.6 kWp PV array for all four MPPT techniques.

5.3.2. PV system perturb and observe

For perturb and observe technique, with varying insolation (same as mentioned in the previous section), it is seen practically that the system becomes unstable and the operating point deviates away. But such situation is not observed in simulation and it still oscillates around the maximum power point as shown in Fig. 17.

5.3.3. *Incremental conductance with varying G and fixed T=300 K*

Fig. 18 shows that the current, voltage and power profiles do not vary much even in varying insolation condition and deliver the maximum power.

5.4. *Comparative assessment of different MPPT techniques under varying G*

The *P–V* curve for the solar PV array is plotted for all the four MPPT techniques under varying solar insolation (*G* is stepped down to 200 W/m^2 from 1000 W/m^2 at 0.1 s, depicting cloudy weather and again it comes to 900 W/m^2 at 0.12 s depicting clearing of the cloudy region) and temperature of 300 K. Fig. 19 shows the *P–V* plots of all the four MPPT techniques.

From Table 3, it is observed that under varying conditions, the total energy extracted half an hour is maximum for variable step size P&O MPPT. To obtain a very good performance, MPP variable step size perturb and observe is used which gives very good performance. In this the step size of the perturbation is varied. Initially it is kept large and when it approaches the MPP point it is reduced. Only disadvantage is that computation time increases.

Table 2
Comparative assessment of different MPPT techniques at fixed solar insolation of 1000 W/m^2 and temperature of 300 K.

Algorithms	Energy (W h)	Oscillation around MPP (W)	Response time (s)
Perturb and observe	749.5	60	0.087
Inc Conductance	768.7	0.8	0.1
Variable step size *P* and *O*	775	0.015	0.21
Constant voltage	755	0.5	0.075

6. Proposed model

As discussed earlier, it is observed that the constant voltage MPPT technique works quite well under uniform insolation and particularly when the solar insolation is low. The response time to achieve the MPP is also low. On the other hand, variable step size P&O works very well in both uniform and varying insolation although the response time is relatively high. In order to get an overall better performance with lesser response time, a Two-Model MPPT Control algorithm is being proposed here (Fig. 20). It combines Constant voltage and the variable step P&O method. If the irradiation is lower than 30% of the nominal insolation level

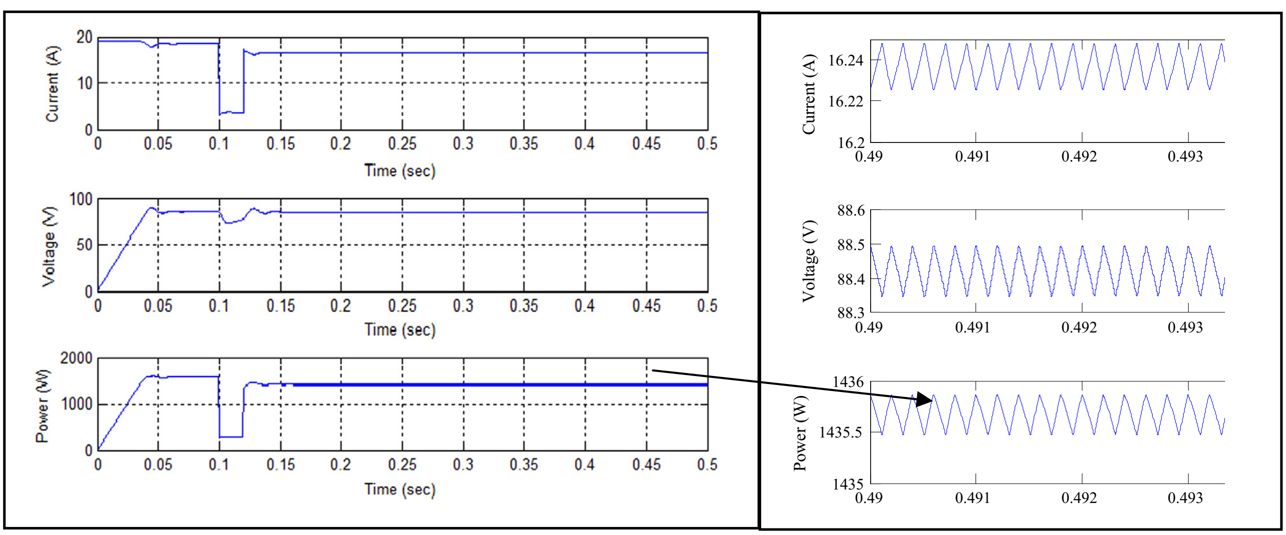

Fig. 16. Power, voltage and current for constant voltage with fixed *T*=300 K and varying *G*.

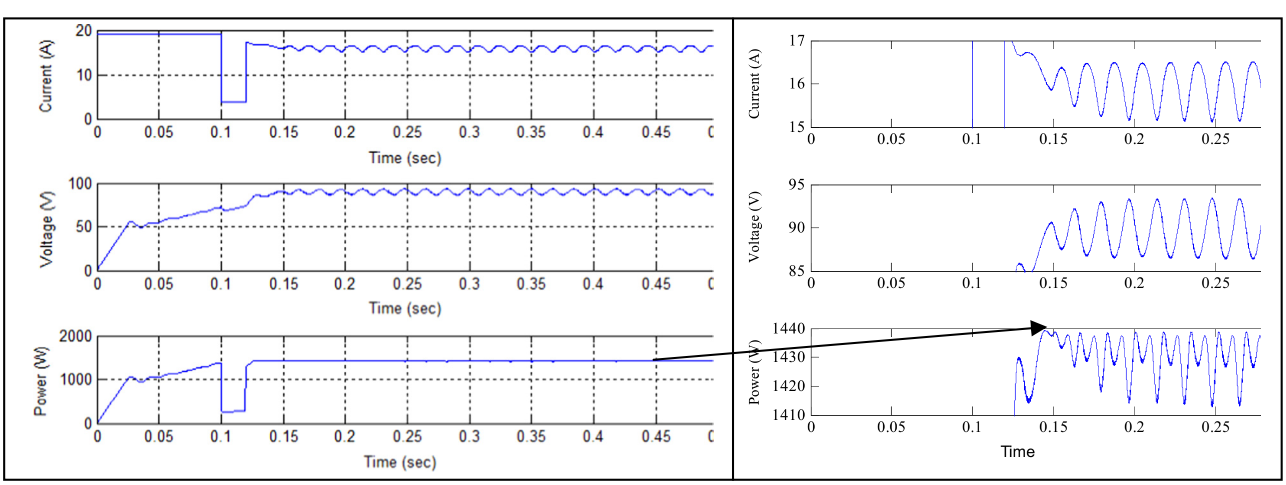

Fig. 17. Power, voltage and current for perturb and observe with fixed *T*=300 K and varying *G*.

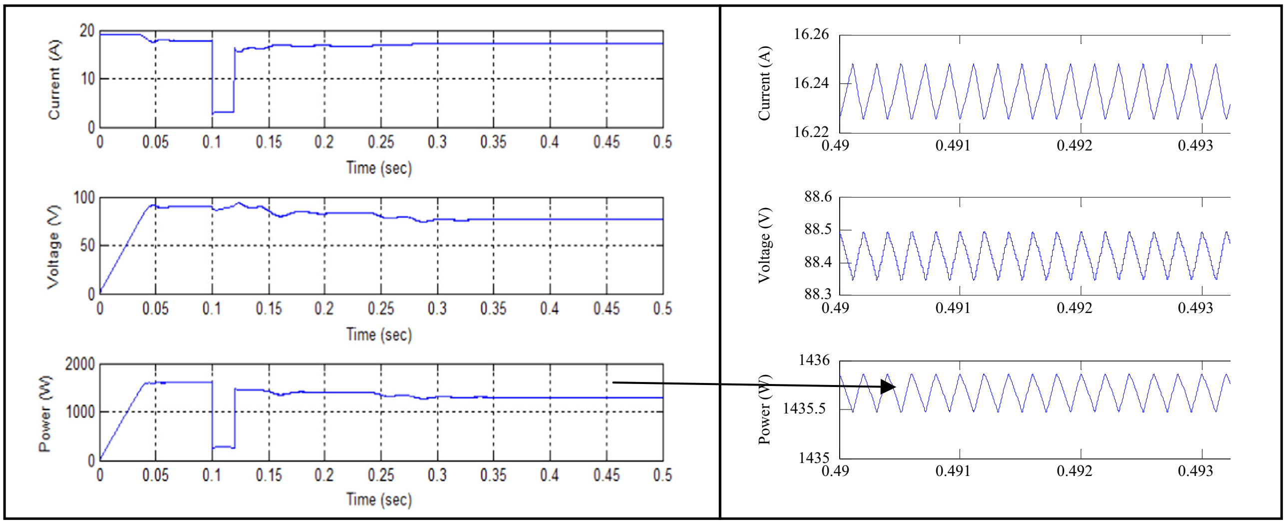

Fig. 18. Power, voltage and current for incremental conductance with fixed T=300 K and varying G.

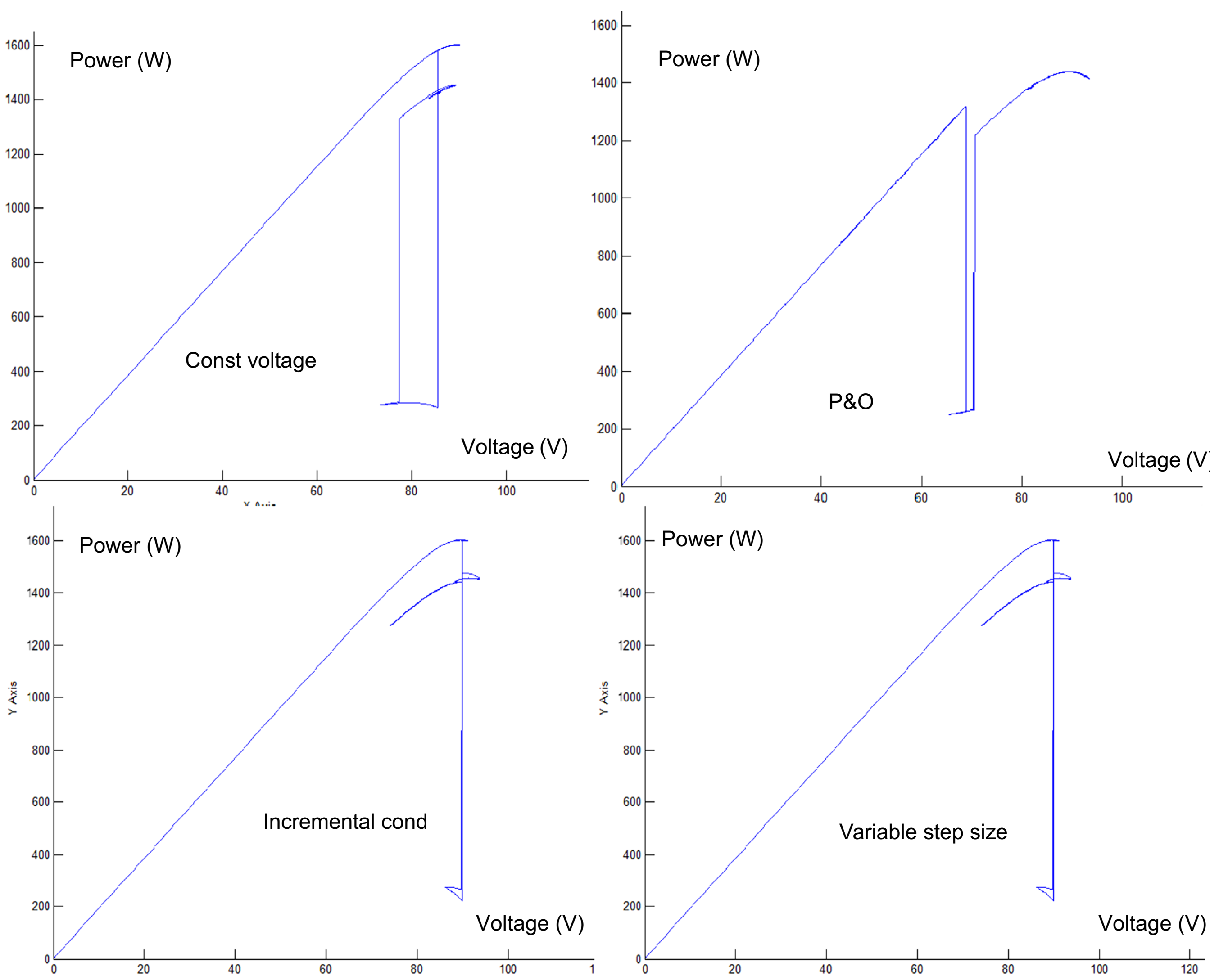

Fig. 19. P–V plots for solar PV array for different MPPT techniques.

the CV method is used, otherwise, variable step P&O method is adopted. Since the short circuit current (I_{sc}) of the PV array is proportional to the insolation, in the model which simulates this proposed MPPT technique, I_{sc} is taken as the indicator of solar insolation.

Fig. 21 shows the power, voltage and current profile of the newly designed two model MPPT techniques.

6.1. Comparison of the proposed MPPT technique with others

The performance of newer two model modified P&O technique is compared with other MPPT techniques and their comparative performances under varying insolations (G is stepped down to 200 W/m^2 from 1000 W/m^2 at 0.1 s, depicting cloudy weather and again it comes to 900 W/m^2 at 0.12 s depicting clearing of the cloudy region) are given in Table 4.

It is observed that under varying conditions, the total energy extracted from the two model modified P&O in half an hour is 2% and 5% more than that of the P&O and constant voltage method, respectively. Although the total energy extracted from the new method is slightly less as compared variable step size P&O (less by 1%), but the response time has drastically reduced from 0.21 s to 0.054 s.

Table 3
Comparative assessment of different MPPT techniques at varying solar insolation and temperature of 300 K.

Algorithm	Energy (W h)	Oscillation around MPP (W)	Response time (s)
Perturb and observe	700	60	0.087
Inc Conductance	720	0.9	0.07
Variable step size *P* and *O*	725	0.015	0.21
Constant voltage	680	0.5	0.05

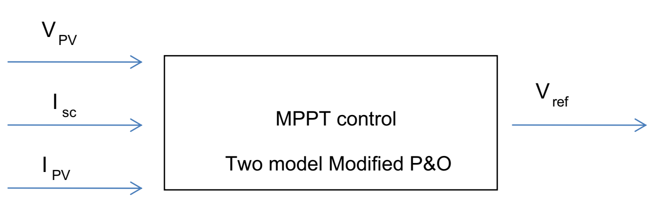

Fig. 20. Proposed MPPT model.

7. Conclusion

The performance assessment of different MPPT techniques used in a 1.6 kW solar PV system for charging the battery is critically assessed under uniform and varying solar insolation. A new two model modified P&O MPPT technique is also developed and compared with other MPPT techniques. From the simulation results, it is observed that under uniform insolation, the constant voltage and P&O MPPT techniques work quite well where as their performance degrades as compared to other MPPT techniques under varying solar insolation. Again under both uniform and varying solar insolation, although the energy generated by using variable step size P&O and Inc Conductance is quite high as compared to other MPPT techniques, the response time in these case are very large, particularly in case of variable step size P&O. Thus a trade-off between energy generated and response time needs to be developed to get the most effective MPPT algorithm. The newly simulated two model modified P&O technique works quite well in both uniform and varying solar insolation condition and is working effectively as a trade-off between energy generated and response time.

Table 4
Comparative assessment of newer developed MPPT technique with other different MPPT techniques at varying solar insolation and temperature of 300 K.

Algorithms	Energy (W h)	Oscillation around MPP (W)	Response time (s)
Perturb and observe	700	60	0.087
Inc Conductance	720	0.9	0.07
Variable step size *P* and *O*	725	0.015	0.21
Constant voltage	680	0.5	0.05
Two model modified P&O	715	0.9	0.054

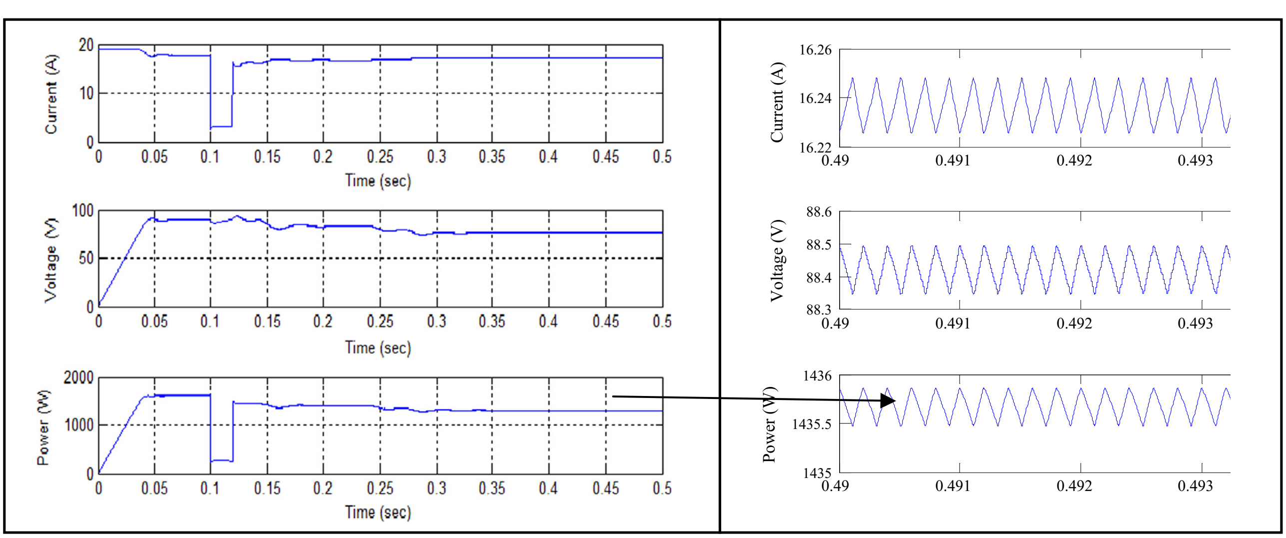

Fig. 21. Power, voltage and current profile of PV system with two model MPPT technique.

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